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RESULTS OF TESTS WITH ELECTRICAL POTENTIAL EQUIPMENT FOR DETECTION OF HIGH RISK PONDEROSA PINES

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In studying the voltage gradients of certain coniferous trees, Mr. Thaddeus Parr of the New Haven, Connecticut, laboratory found that his electrical potential equipment gave surprisingly accurate results in predicting those trees which would succumb to injury, even before there was any outward sign of approaching death. Dr. Craighead suggested that this equipment might also be useful in determining high risk ponderosa pines, and accordingly arrangements were made to send out a set of the equipment for trial in this connection.

One of the voltage gradient potentiometers and a pair of silver-silver chloride electrodes with necessary supplemental equipment were prepared by Parr and shipped to Bly, Oregon, where it was to be tested. He also prepared a set of detailed instructions which were essential in operating the set and necessitated merely the following of instructions.

Tests were run during the latter part of September and early October of 1941 at Meryl Springs near Bly, Oregon. Eighty trees were selected for this purpose, comprising five trees in each of the 16 Keen tree classes. During the earlier preliminary tests, Mr. F. P. Keen and Dr. R. C. Hall were present and assisted in the testing of the equipment.

PROCEDURE

The procedure consisted of adhering closely to the instructions outlined by Parr. Particular care was taken to be certain that the holes for placement of electrodes in the tree were always 12 inches apart in a vertical direction and penetrated only to the current year's radial growth tissues; that a sufficient quantity of 0.9 percent normal sodium chloride solution was present in each hole to ensure good contact between electrode and tree tissue; that the galvanometer was balanced immediately before each reading was taken; that no wind or other movement caused the lead wires to move between the time the galvanometer was balanced and the reading was made; that the "hot" electrode was always placed nearest the base of the tree, and that the same lead wire was always connected with the same electrode and battery terminal.

Before making final readings on any of the 80 trees selected for this test, a sufficient amount of practice was done to make certain that the equipment was being properly used and to provide some skill in its use. In these preliminary tests it was found that reasonably constant readings could be secured on any one tree regardless of time of day or date over a period of three weeks, cloudiness, side of tree, or height of electrodes above the base of the tree within easy working distance of the ground. However, movement of lead wires by wind or other cause made the galvanometer needle oscillate and necessitated rebalancing the potentiometer.

RESULTS

Following the preliminary tests to facilitate proper operation of the equipment, readings were taken from each of the 80 trees selected for this purpose. These results are recorded in tables 1 and 2. In table 1, the readings are arranged according to the mortality ratios set up for Keen's tree classes, from the lowest to the highest mortality. In table 2, a similar arrangement has been made according to the California risk classes.

Table 1

Galvanometer Readings Secured with Silver-Silver Chloride Electrode in Ponderosa Pine Arranged According to Keen Tree Class Mortality Ratios

	Tree Class[1]	Number negative readings	Galvanometer reading in millivolts: Reading range		Mean[2]	Mean total deflection[3]
Lowest mortality	1A	4	-10	+2	-4.6	5.4
	1B	3	-5	+3	-1.1	3.1
	2A	4	-9	+8	-2.0	6.8
	3A	3	-7	+2.5	-2.8	4.6
	1C	3	-5	+3	-1.3	3.7
	2B	4	-7	+3	-3.8	5.0
	3B	4	-9	+4	-3.9	5.5
	4A	3	-11.5	+9	-2.5	7.5
	1D	4	-8	+5	-3.8	5.8
	2C	4	-9	+5	-5.6	7.6
	3C	3	-5	+6	-0.4	4.4
	4B	3	-6	+7	0	5.2
	2D	3	-8	+6.5	-1.7	6.3
	3D	3	-8	+7	-0.5	5.5
	4C	3	-10	+8	-2.6	7.0
Highest mortality	4D	3	-7	+3	-2.2	4.6

1/ Five trees in each tree class

2/ Arithmetic mean secured by adding plus and minus deflections and dividing remainder by number of observations.

3/ Mean total deflection secured by adding deflections without regard to sign and dividing by number of observations.

Table 2

Galvanometer Readings Secured with Silver-Silver Chloride Electrode in Ponderosa Pine Arranged According to California Risk Classes

	Risk class	Number trees	Percent negative readings	Galvanometer readings in millivolts: Reading range		Mean	Mean total deflection
Lowest mortality	1	33	75.7	-11.5	+8	-3.6	5.1
	2	12	41.6	-9	+9	+0.5	5.2
	3	19	57.8	-9	+8	-1.3	5.8
Highest mortality	4	16	75.0	-10	+7	-3.7	5.9

In these two tables, the ranges in readings are so wide and the means and direction of gradient so varied that there is no evidence of a relationship between the readings and the risk or tree classes.

It was thought that a consolidation of Table 1 might show some degree of correlation between the galvanometer readings and grouped tree classes. Such a consolidation is shown in table 3.

Table 3

GALVANOMETER READINGS SECURED WITH SILVER-SILVER CHLORIDE ELECTRODE IN PONDEROSA PINE

Trees grouped into least and most susceptible tree classes

Tree classes	Number negative readings	Galvanometer reading in millivolts: Reading range	Mean	Mean total deflection
1A, 1B, 2A, 3A 1C, 2B, 3B, 4A	28 out of 40	-11.5 +9	-2.7	5.0
1D, 2C, 3C, 4B 2D, 3D, 4C, 4D	26 out of 40	-10 +8	-2.0	5.7
Difference			-0.7	0.7
Standard error of average			.171	.087
Least significance 5% level			2.306	2.306
Significance			None	None

Table 3 shows a small difference in both the arithmetic mean and the mean total deflection. However, when a test for significance was applied, it was found that these differences were meaningless.

DISCUSSION

It is obvious that the readings from the potentiometer had little relation to what we have come to recognize as susceptible or high risk trees. Since there is no question but what high risk trees are in poorer health than low risk trees, the question arises as to what the readings of the potentiometer mean.

In correspondence, Parr suggested that the irregular gradients may be due to the fact that the readings were taken at a time when the trees were undergoing the fall reversal in gradient which he believes accompanies the increased synthesis of fats and oils in the tree. This appears improbable, however, because Clements has shown that fat and oil synthesis in Douglas-fir and ponderosa pine accompanies reduced temperatures and occurs quite early in the fall in east-central Washington. In the light of this work, we can feel certain that the pines tested with the vacuum tube voltmeter had already hardened themselves for winter since the Meryl Springs area had had freezing night temperatures since early September.

Mr. A. W. Andrews, professor of Physics at Multnomah College, and his colleagues in electrical engineering and radio were consulted to secure authoritative information concerning the abilities of this voltage gradient equipment. Mr. Andrews first tested the electrodes and the potentiometer. He found the electrodes to be in balance and the potentiometer to give accurate readings within its limits. The next step was to test two Douglas-fir trees—one a full-crowned dominant and the other a scraggly-crowned, severely suppressed tree. Both gave negative readings (the base electropositive to the top) on March 7, 1942. Mr. Andrews next set up a series of laboratory tests to determine what was most effective in influencing the galvanometer readings and found greatest response to pH. Since the electrodes were in balance, the degree of ionization could be read on either side of the galvanometer scale, depending on which electrode was placed first in the solution.

With this basic information, a small amount of literature was examined in search of a possible explanation for the variable gradients in ponderosa pine. It was found that there is a steady but variable flow of electric current along the earth's surface, that there is an ever-present but variable amount of electricity in the atmosphere, that there is a constant interchange of electricity between the earth and the atmosphere, that this interchange occurs partly through trees, that there is a photoelectric discharge associated with chlorophyll, that voltage gradients are used by plant physiologists to explain translocation and other photochemical reactions within the plant, and that this photoelectric response is apparently dependent upon metabolic activity. These findings would lead to the assumption that in a living tree, the voltage gradients would vary in direction and degree depending on numerous interacting factors. In effect, this is actually what has been found. Lund recorded that in the Douglas-fir, although the tip was normally electropositive to the base, the voltage gradients varied, reversed, and even opposed each other.

This leads to the conclusion that the ponderosa pine trees used in this test were living trees which gave a normal rather than an unusual reaction. Trees immediately susceptible to beetle attack, or those suffering from severe injury such as fire, defoliation, etc., no doubt would give a different reaction and probably would come within the scope of the voltage gradient equipment. However, the ponderosa pine tree susceptibility work necessitates the selection of trees which will be attacked by the beetles from five to ten years hence. Thus, it is believed that the present set-up of equipment is not applicable to the ponderosa pine work. However, the determination of voltage gradients does offer a possibility and may prove helpful when it is possible to determine the gradient for one definite physiological process which differs between susceptible and non-susceptible trees.

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